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Kanno

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(54) **LASER DIODE DRIVING DEVICE AND OPTICAL SCANNING DEVICE**

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(52) **U.S. Cl.** **372/38.02**; 372/38.1

(58) **Field of Classification Search** 372/38.02, 372/38.1

See application file for complete search history.

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(57) **ABSTRACT**

A laser diode driving device capable of obtaining a stable pulse emission state even when variation in the current-light amount characteristic of a laser diode thereof is caused by environmental changes. A photodiode detects the amount of light emitted from the laser diode. A laser controller determines the amount of light to be emitted from the laser diode. Further, the laser controller controls the laser diode to emit light in the determined light amount. A bias current value-determining section determines a bias current value based on results of light emission performed by the laser diode in three or more kinds of light amounts determined by the laser controller.

10 Claims, 7 Drawing Sheets

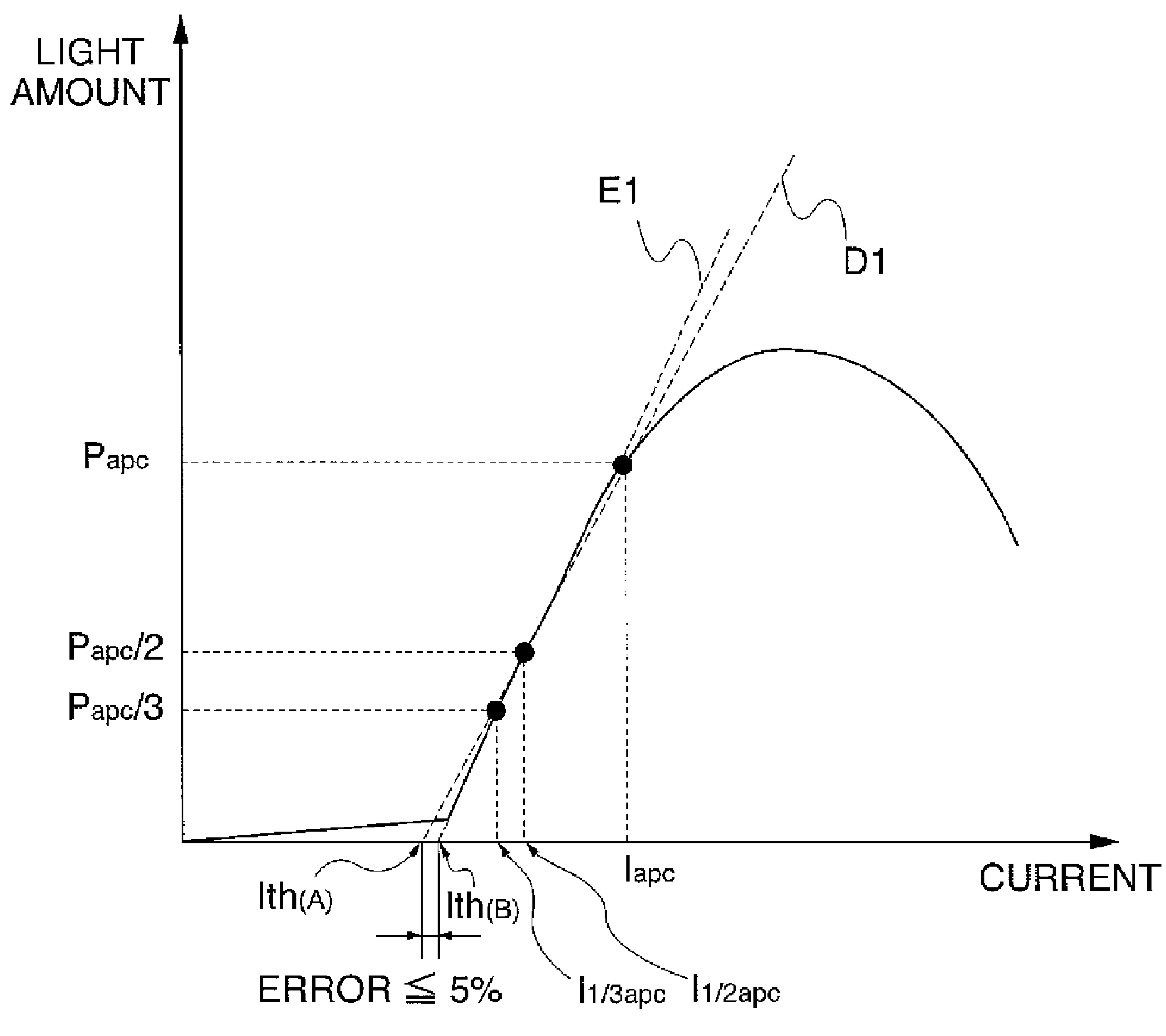


FIG. 1

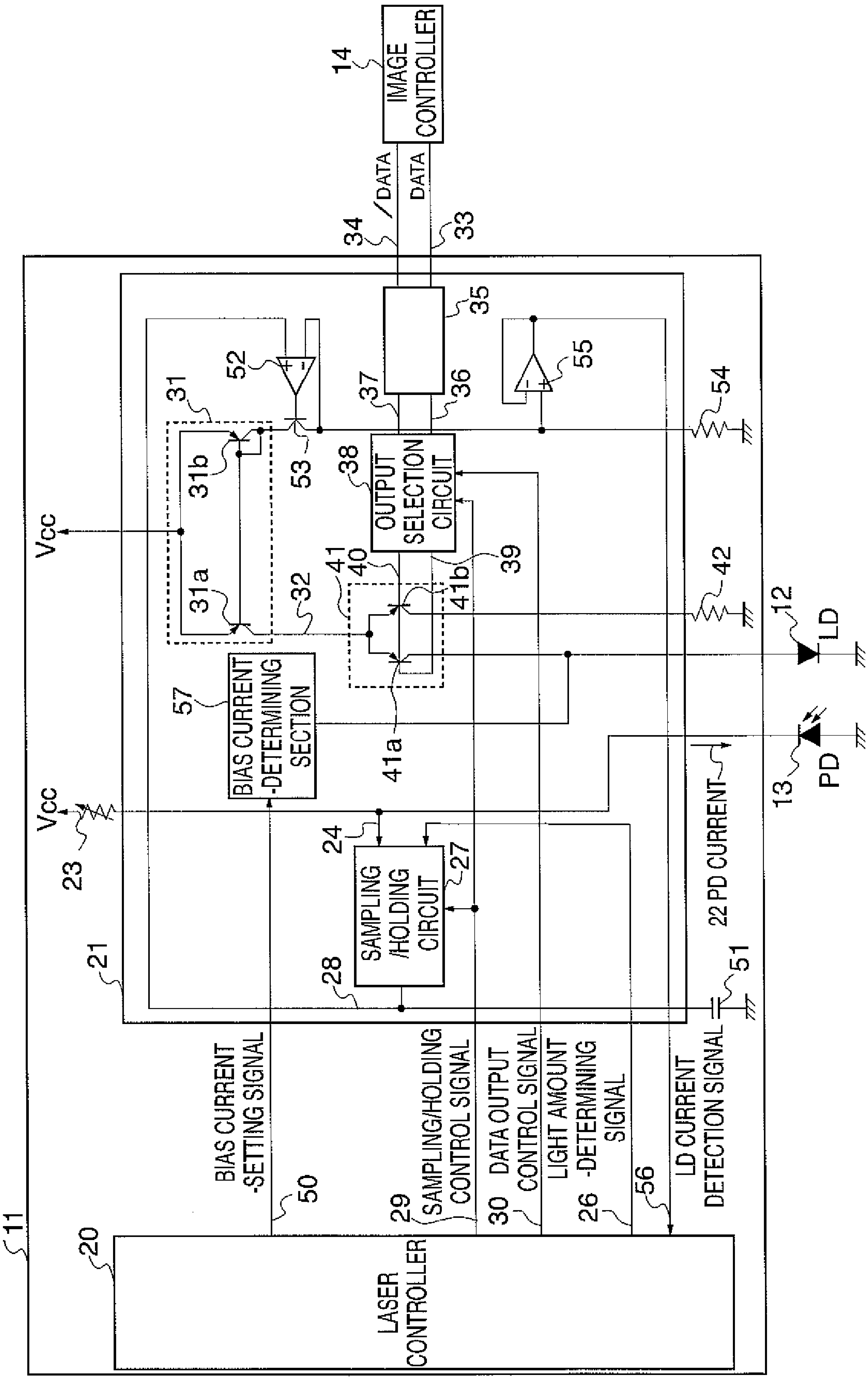


IMAGE CONTROLLER
14
/DATA
DATA
34
33
35
36
37
52
55
54
31
31b
53
38
OUTPUT SELECTION CIRCUIT
Vcc
31a
32
41
40
41b
39
42
12
LD
57
BIAS CURRENT -DETERMINING SECTION
41a
13
PD
Vcc
23
24
27
SAMPLING /HOLDING CIRCUIT
22 PD CURRENT
21
28
51
BIAS CURRENT -SETTING SIGNAL
SAMPLING/HOLDING CONTROL SIGNAL
DATA OUTPUT CONTROL SIGNAL
LIGHT AMOUNT -DETERMINING SIGNAL
LD CURRENT DETECTION SIGNAL
50
29
30
26
56
11
20
LASER CONTROLLER

FIG. 2

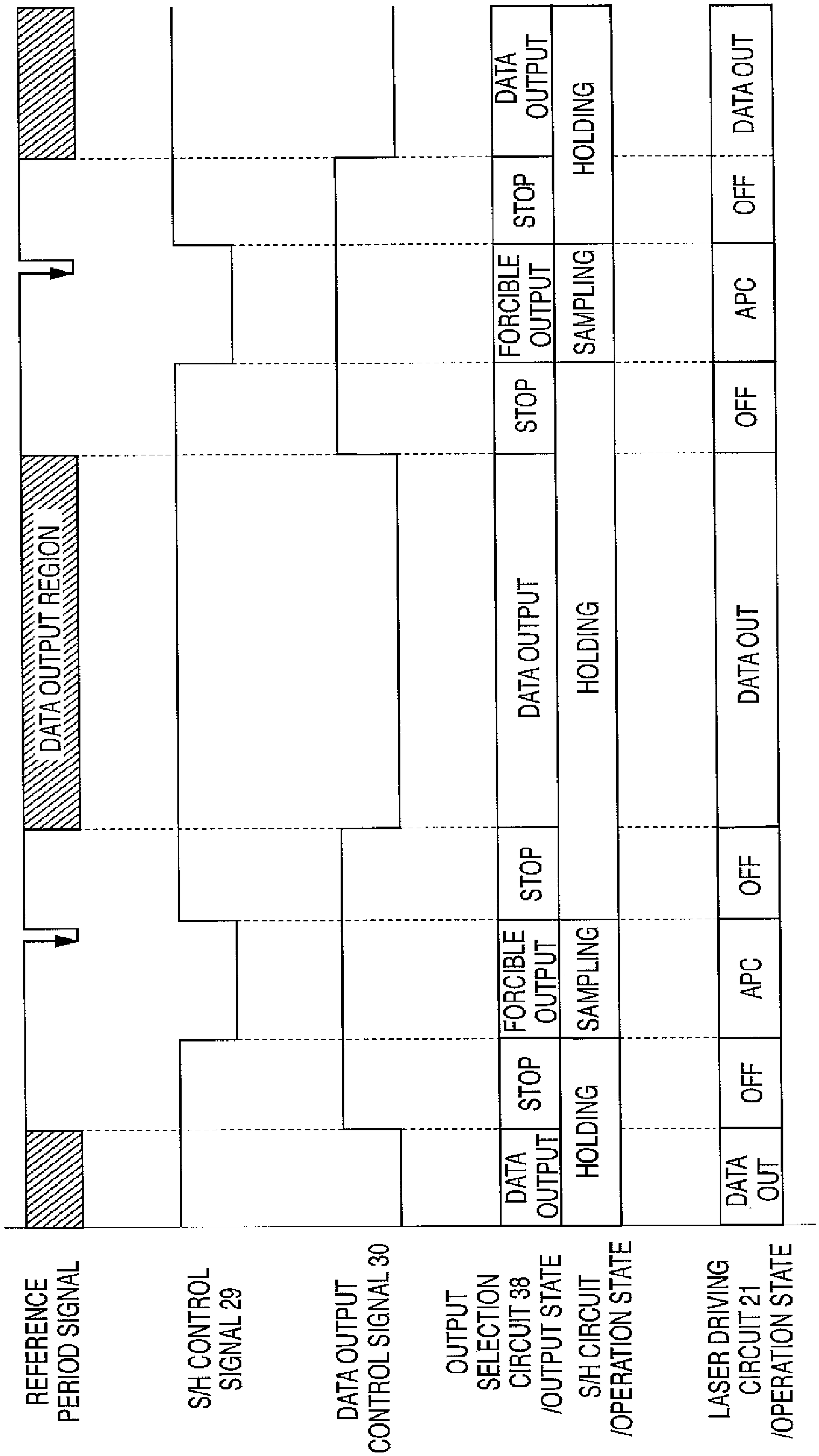

REFERENCE PERIOD SIGNAL
S/H CONTROL SIGNAL 29
DATA OUTPUT CONTROL SIGNAL 30
OUTPUT SELECTION CIRCUIT 38 /OUTPUT STATE
S/H CIRCUIT /OPERATION STATE
LASER DRIVING CIRCUIT 21 /OPERATION STATE
DATA OUTPUT REGION
DATA OUTPUT
STOP
FORCIBLE OUTPUT
STOP
DATA OUTPUT
STOP
FORCIBLE OUTPUT
STOP
DATA OUTPUT
HOLDING
SAMPLING
HOLDING
SAMPLING
HOLDING
DATA OUT
OFF
APC
OFF
DATA OUT
OFF
APC
OFF
DATA OUT

FIG. 3

S/H CONTROL SIGNAL 29	DATA OUTPUT CONTROL SIGNAL 30	S/H CIRCUIT 27	OUTPUT SELECTION CIRCUIT 38	LASER DRIVING CIRCUIT 21 /OPERATION STATE
L	H	SAMPLING	FORCIBLE OUTPUT	LIGHT AMOUNT CONTROL (APC)
H	H	HOLDING	STOP	FORCIBLE LASER OFF
H	L	HOLDING	DATA OUTPUT	DATA OUTPUT
L	L	"0" (INITIAL VALUE)	STOP	RESET STATE

FIG. 4

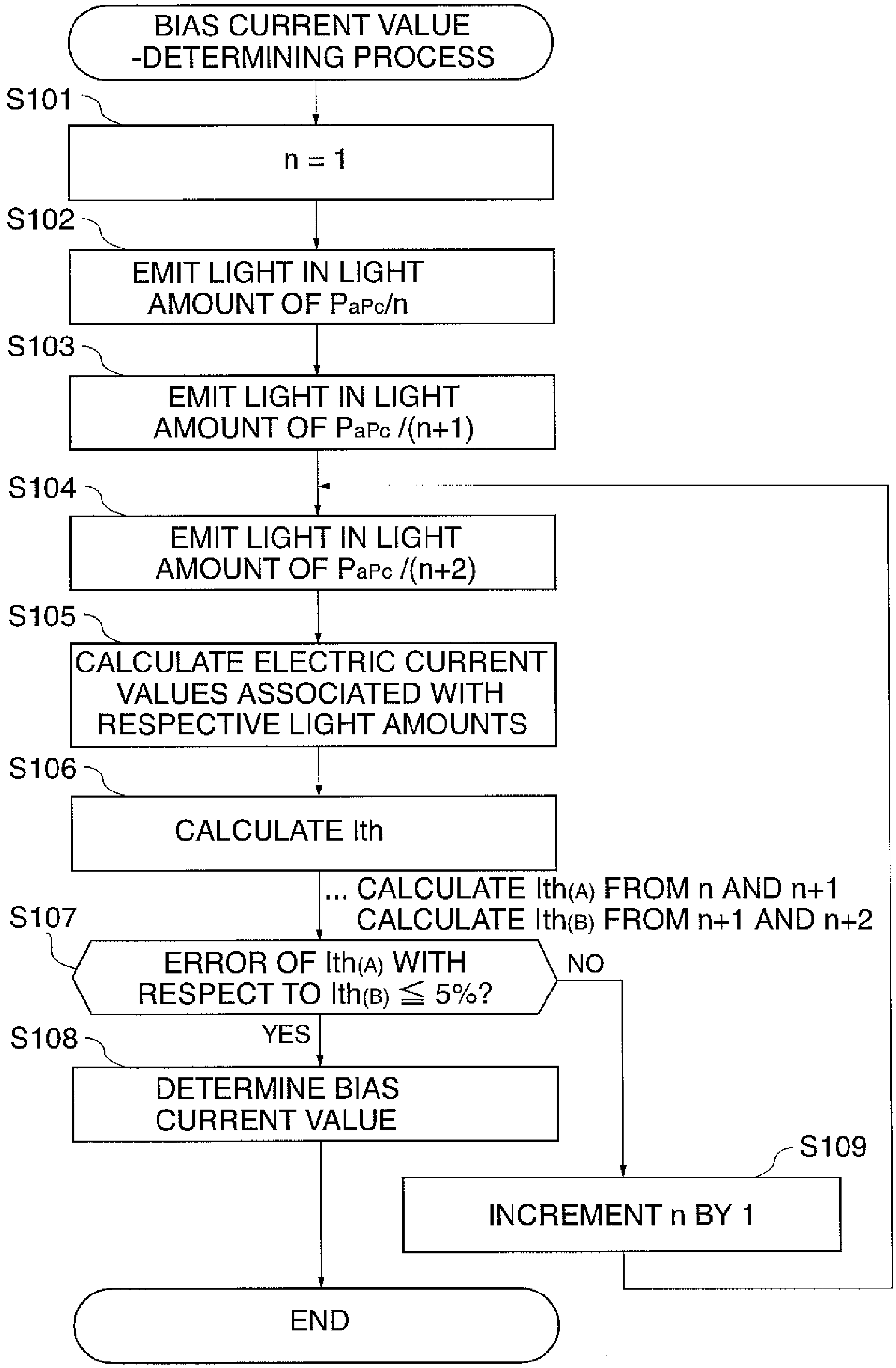

BIAS CURRENT VALUE -DETERMINING PROCESS
S101
n = 1
S102
EMIT LIGHT IN LIGHT AMOUNT OF PaPc/n
S103
EMIT LIGHT IN LIGHT AMOUNT OF PaPc /(n+1)
S104
EMIT LIGHT IN LIGHT AMOUNT OF PaPc /(n+2)
S105
CALCULATE ELECTRIC CURRENT VALUES ASSOCIATED WITH RESPECTIVE LIGHT AMOUNTS
S106
CALCULATE Ith
... CALCULATE Ith(A) FROM n AND n+1
CALCULATE Ith(B) FROM n+1 AND n+2
S107
ERROR OF Ith(A) WITH RESPECT TO Ith(B) ≦ 5%?
NO
YES
S108
DETERMINE BIAS CURRENT VALUE
S109
INCREMENT n BY 1
END

FIG. 5

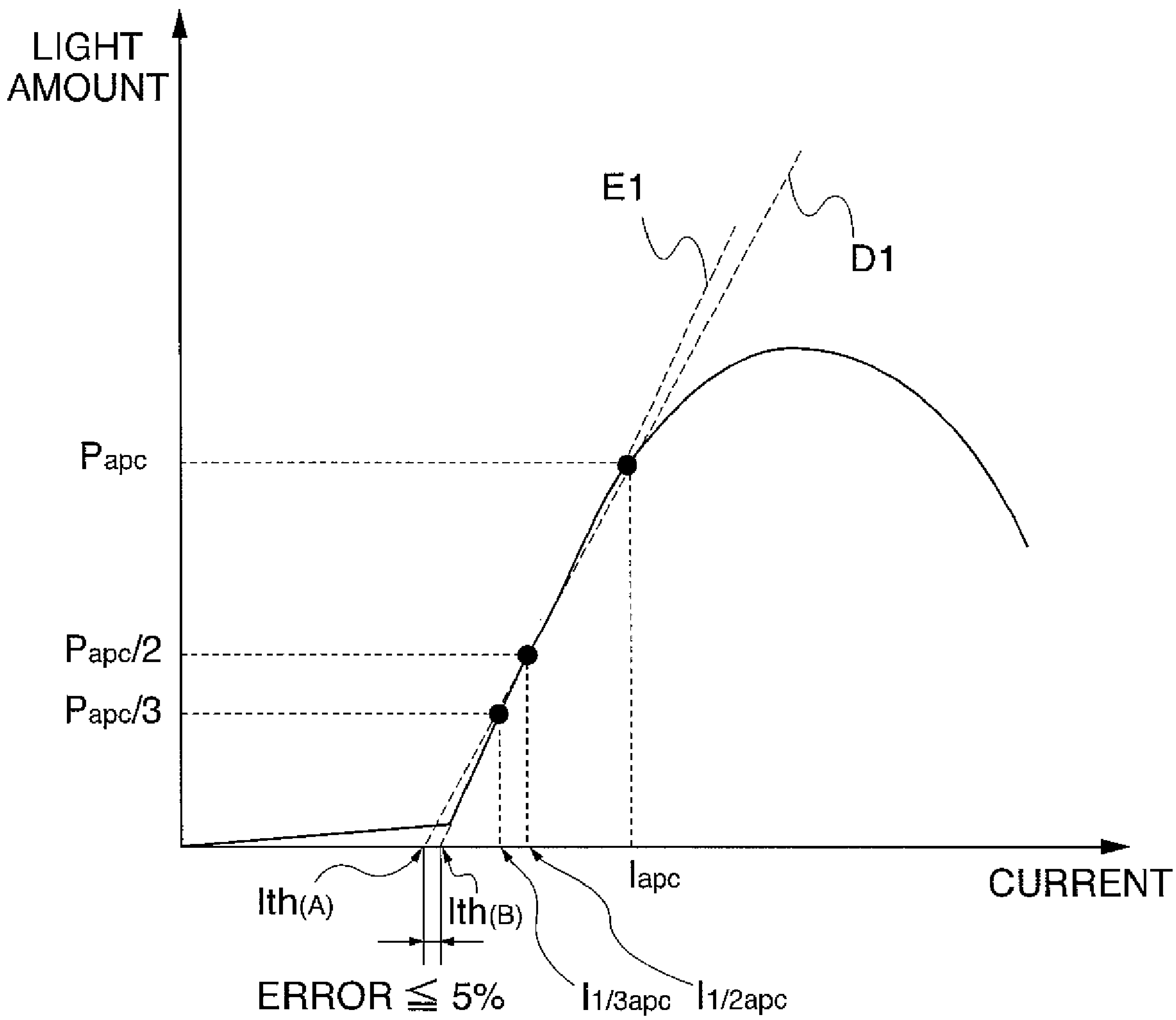

LIGHT AMOUNT
E1
D1
Papc
Papc/2
Papc/3
Ith(A)
Ith(B)
Iapc
CURRENT
ERROR ≦ 5%
I1/3apc
I1/2apc

FIG. 6

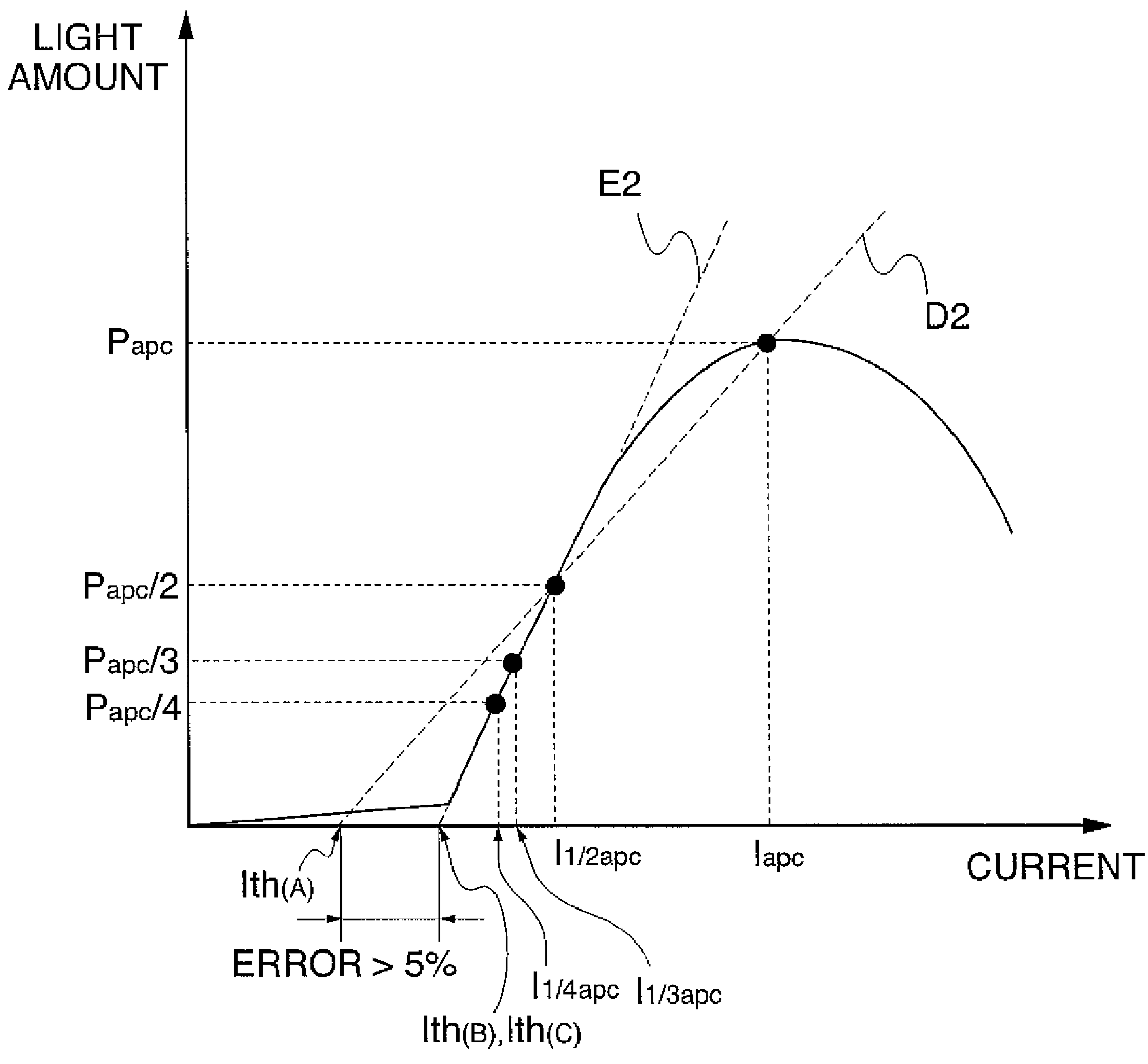

LIGHT AMOUNT
E2
D2
Papc
Papc/2
Papc/3
Papc/4
I1/2apc
Iapc
CURRENT
Ith(A)
ERROR > 5%
I1/4apc
I1/3apc
Ith(B), Ith(C)

FIG. 7B

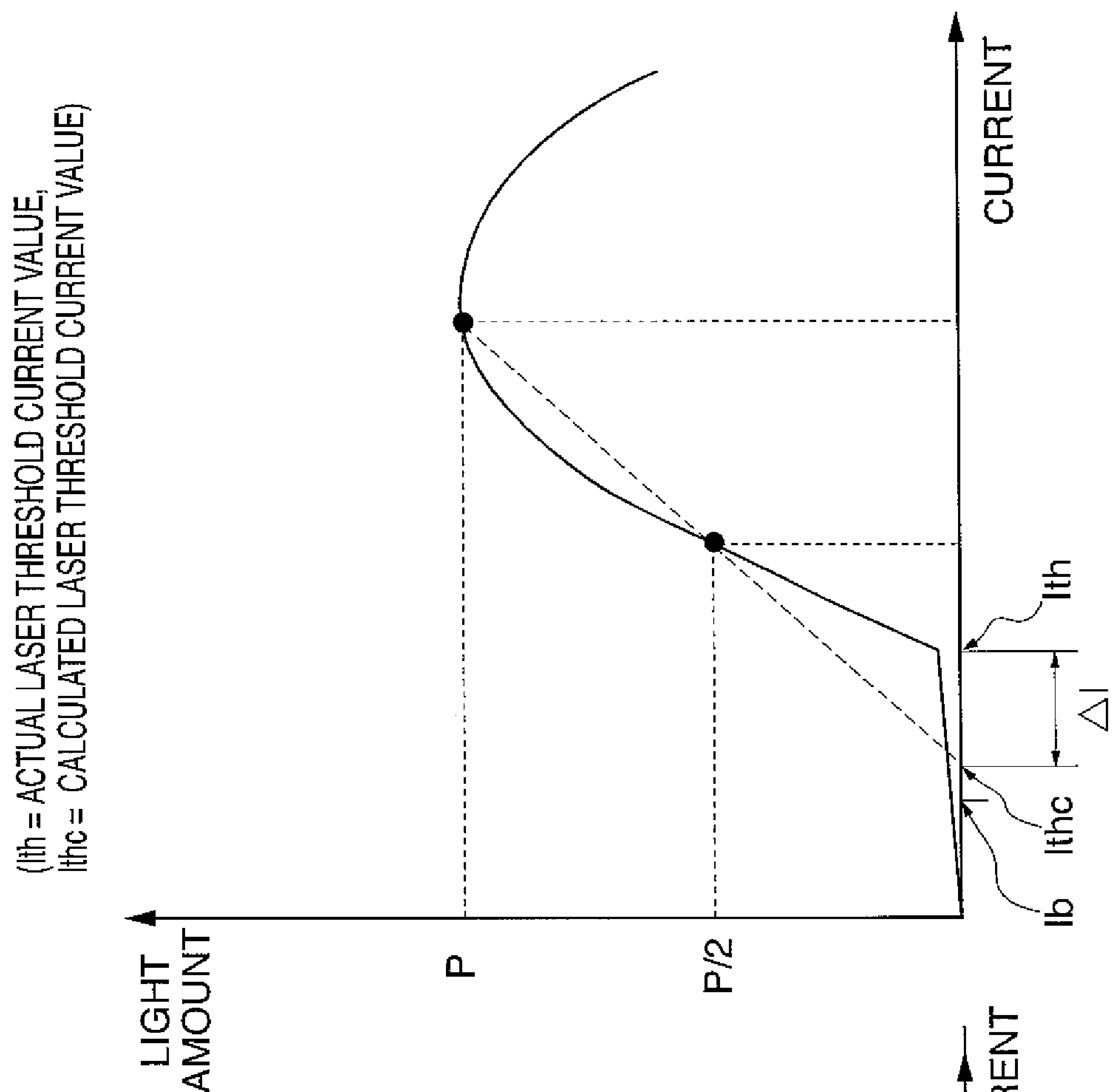
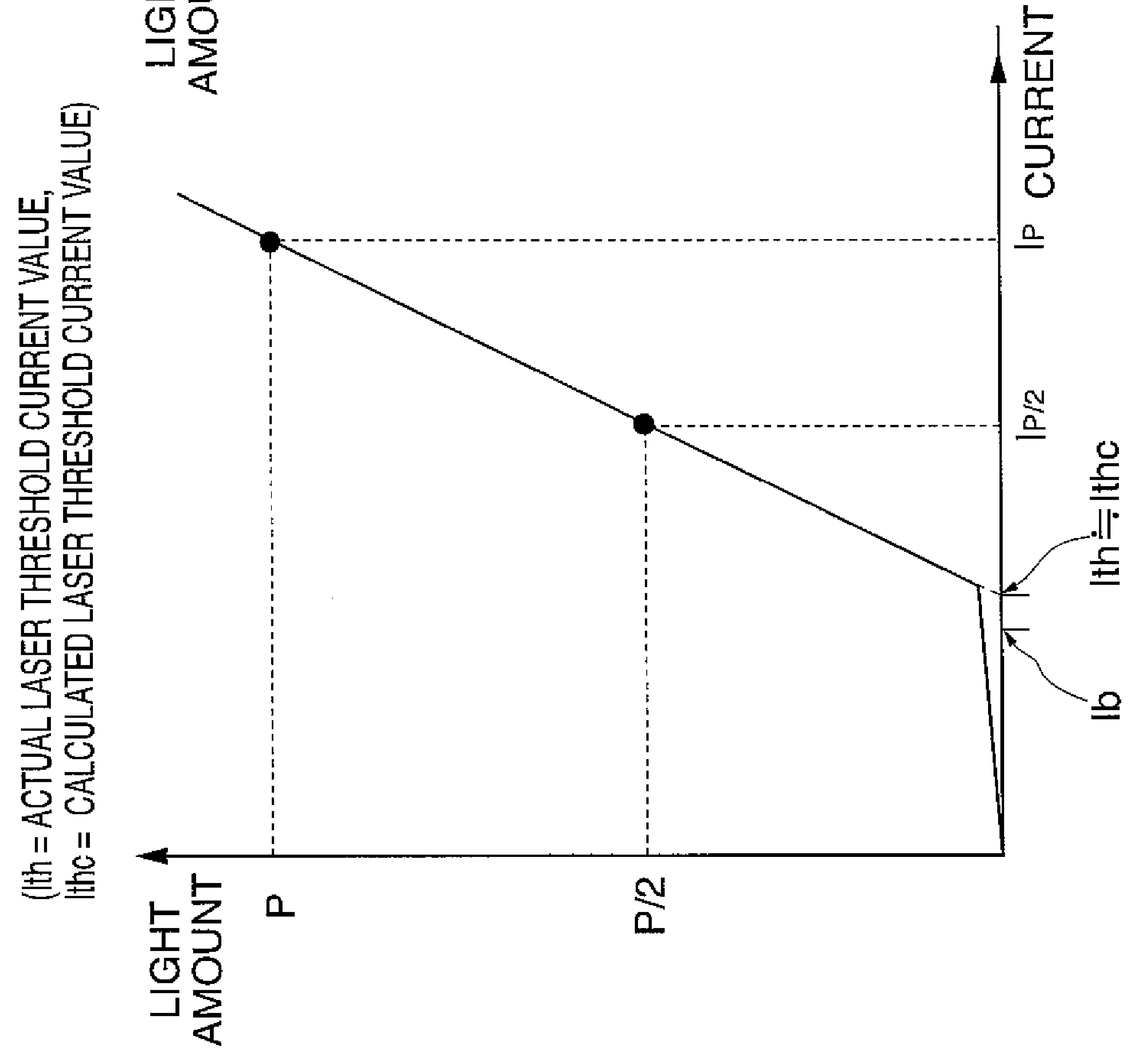

(Ith = ACTUAL LASER THRESHOLD CURRENT VALUE,
Ithc = CALCULATED LASER THRESHOLD CURRENT VALUE)
LIGHT AMOUNT
P
P/2
CURRENT
Ib
Ithc
ΔI
Ith

FIG. 7A


(Ith = ACTUAL LASER THRESHOLD CURRENT VALUE,
Ithc = CALCULATED LASER THRESHOLD CURRENT VALUE)
LIGHT AMOUNT
P
P/2
CURRENT
Ib
Ith ≒ Ithc
IP/2
IP

LASER DIODE DRIVING DEVICE AND OPTICAL SCANNING DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a laser diode driving device and an optical scanning device.

2. Description of the Related Art

There has been proposed a technique related to a laser diode driving device, in Japanese Patent Laid-Open Publication No. H11-245444, in which the value of a bias current to be applied to a laser diode is determined based on two amounts of laser emission and current values corresponding to the respective amounts of laser emission.

However, the conventional technique has a problem with a method of calculating the bias current to be applied to the laser diode.

A laser diode, particularly a VCSEL (semiconductor vertical-cavity surface-emitting laser) sometimes has a current-light amount characteristic which assumes an extreme value as shown in FIG. **6**. In a case where the current-light amount characteristic assumes an extreme value, when a threshold current value Ithc of the laser diode is calculated based on the two amounts of laser emission and the current values corresponding thereto, the threshold current value Ithc deviates from an actual threshold current value Ith by ΔI as shown in FIGS. **7**A and **7**B.

A bias current value Ib is calculated based on the obtained threshold current value Ithc, and hence the value Ib to be set close to the target value Ith deviates therefrom. When the bias current value deviates from the target value, the light emitting characteristics of the laser become unstable. For example, when the laser is used in an optical communication apparatus, troubles occur in data transmission. Further, when the laser is used in an image forming apparatus, variation occurs in output of highlight-side density depending on the environment.

SUMMARY OF THE INVENTION

The present invention provides a laser diode driving device and an optical scanning device which are capable of obtaining a stable pulse emission state even when variation in the current-light amount characteristic of a laser diode thereof is caused by environmental changes.

In a first aspect of the present invention, there is provided a laser diode driving device comprising a light amount-detecting unit adapted to detect an amount of light emitted from a laser diode, a light amount-determining unit adapted to determine an amount of light to be emitted from the laser diode, a light amount control unit adapted to control the laser diode to emit light in the light amount determined by the light amount-determining unit, and a bias current value-determining unit adapted to determine a bias current value based on results of tight emission performed by the laser diode in three or more light amounts determined by the light amount-determining unit.

In a second aspect of the present invention, there is provided an optical scanning device comprising a light amount-detecting unit adapted to detect an amount of light emitted from a laser diode, a light amount-determining unit adapted to determine an amount of light to be emitted from the laser diode, a light amount control unit adapted to control the laser diode to emit light in the light amount determined by the light amount-determining unit, and a bias current value-determining unit adapted to determine a bias current value based on

results of light emission performed by the laser diode in three or more light amounts determined by the light amount-determining unit.

The laser diode driving device and the optical scanning device are provided with the light amount-detecting unit adapted to detect the amount of light emitted from a laser diode, the light amount-determining unit adapted to determine the amount of light to be emitted from the laser diode, and the light amount control unit adapted to control the laser diode to emit light in the light amount determined by the light amount-determining unit. Further, the devices have the bias current value-determining unit adapted to determine a bias current value based on results of light emission performed by the laser diode in three or more light amounts determined by the light amount-determining unit.

With this configuration, a stable pulse emission state can be obtained even when variation in the current-light amount characteristic of the laser diode is caused by environmental changes.

The features and advantages of the invention will become more apparent from the following detailed description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of a laser diode driving device according to an embodiment of the present invention.

FIG. **2** is a timing diagram of a control sequence executed by the laser diode driving device in FIG. **1**.

FIG. **3** is a table of laser control modes performed by the laser diode driving device in FIG. **1**.

FIG. **4** is a flowchart of a bias current-determining process executed by the laser diode driving device in FIG. **1** so as to determine a bias current to be applied to an LD.

FIG. **5** is a diagram showing a characteristic of a semiconductor laser (laser diode) appearing in FIG. **1** (No. **1**).

FIG. **6** is a diagram showing a characteristic of the semiconductor laser (laser diode) appearing in FIG. **1** (No. **2**).

FIGS. **7**A and **7**B are diagrams showing characteristics of a conventional laser diode.

DETAILED DESCRIPTION OF THE EMBODIMENTS

The present invention will now be described in detail with reference to the drawings showing an embodiment thereof.

FIG. **1** is a block diagram of a laser diode driving device according to the embodiment of the present invention.

Connected to the laser diode driving device **11** are a semiconductor laser (laser diode: hereinafter abbreviated as "the LD") **12**, a photodiode (hereinafter abbreviated as "the PD") **13**, and an image controller **14**.

The laser diode driving device **11** is comprised of a laser controller **20** and a laser driving circuit **21**. A drive current to be supplied to the LD **12** is controlled by the laser driving circuit **21**, whereby the LD **12** is caused to constantly emit a predetermined amount of light.

The laser controller **20** functions as a light amount-determining unit for determining the amount of light to be emitted from the LD **12**. The laser controller **20** also functions as a light amount control unit for controlling the LD **12** so as to cause the same to emit an amount of light determined by the light amount-determining unit.

The PD **13** as a light amount-detecting unit for monitoring a laser beam output from the LD **12** (i.e. detecting the amount of light from the laser diode) outputs an electric current corresponding to the light amount of the monitored laser beam. A light amount-adjusting variable resistor **23** performs adjustment such that the LD **12** emits a predetermined amount of light.

The electric current (PD current) **22** output from the PD **13** according to the light amount of the monitored laser beam is converted into voltage by the light amount-adjusting variable resistor **23** and is output as a PD voltage signal **24**. The PD voltage signal **24** is input to a sample/hold circuit **27** together with a light amount-determining signal **26** output from the laser controller **20**.

When a sample/hold (hereinafter abbreviated as S/H) control signal **29** output from the laser controller **20** requests sampling, the sample/hold circuit **27** makes a comparison between the PD voltage signal **24** and the light amount-determining signal **26**.

Then, when the PD voltage signal **24** is lower than the light amount-determining signal **26**, the PD voltage signal **24** is charged in a hold capacitor **51**, whereas when the PD voltage signal **24** is higher than the light amount-determining signal **26**, the PD voltage signal **24** is discharged from the hold capacitor **51**. Thus, a voltage value **28** dependent on the PD current **22** output from the PD **13** is caused to increase or decrease, whereby the LD **12** is controlled to the predetermined amount of light.

When the S/H control signal **29** requests holding, the voltage value **28** determined based on a result obtained depending on the PD current **22** when sampling was requested is held in the hold capacitor **51**.

A current mirror circuit **31** as a current control circuit is comprised of transistors **31***a* and **31***b*. The mirror ratio of the current mirror circuit **31** is set to e.g. approximately 40. When data output is requested, the voltage value **28** output from the sample/hold circuit **27**, which is dependent on the PD current **22** output from the PD **13**, is input to the positive input terminal of an operational amplifier **52** in response to the S/H control signal **29** input from the laser controller **20**. As a consequence, an electric current output from the emitter of a transistor **53** flows through a resistor **54**.

It should be noted that the value of voltage generated across the resistor **54** is output as an LD current detection signal **56** to the laser controller **20** via an operational amplifier **55**. Since the mirror ratio of the current mirror circuit **31** is set to approximately 40, a laser drive current **32** output from a collector side of the transistor **31***a* of the current mirror circuit **31** becomes approximately 40 times larger than the current flowing through the resistor **54**.

A differential receiver (LVDS) **35** having a differential input receives a non-inverted data signal **33** and an inverted data signal **34** each input from the image controller **14**. An output selection circuit **38** outputs a first switching signal **39** or a second switching signal **40** determined by the S/H control signal **29** or a data output control signal **30**.

A current driver **41** has transistors **41***a* and **41***b* and is configured as a differential amplifier by connecting emitter terminals of the respective transistors **41***a* and **41***b* to each other. The transistor **41***a* switchingly drives the LD **12** based on the first switching signal **39**, using the laser drive current **32**. Similarly, the transistor **41***b* switchingly drives a load resistor **42** based on the second switching signal **40**, using the laser drive current **32**.

A bias current-determining section **57** outputs an electric current according to a bias current-setting signal **50** such that the ratio of a value of a bias current supplied to the LD **12** to a laser threshold current value Ith of the LD **12** or the amount of the bias current does not change.

The function of the bias current-determining section **57** as a bias current value-determining unit will be described in more detail.

The bias current-determining section **57** determines a bias current value based on the values of respective electric currents applied to the LD **12** when the LD **12** is caused to emit light in two different amounts.

Further, the bias current-determining section **57** determines a bias current value through comparison between bias current values obtained from the values of the respective electric currents applied to the LD **12** when the LD **12** is caused to emit light in the two different amounts.

Furthermore, the bias current-determining section **57** determines a bias current value based on the values of respective electric currents applied to the LD **12** when the LD **12** is caused to emit light in two amounts except a maximum amount which are selected from a three or more amounts.

Now, various kinds of laser control modes performed by the laser diode driving device **11** in FIG. **1** will be described with reference to FIGS. **2** and **3**.

(1) When the laser diode driving device **11** is in a laser control mode in which the laser driving circuit **21** is set to perform automatic light amount control ("APC (Automatic Power Control)), and the sample/hold circuit **27** is in a sampling state, the output selection circuit **38** forcibly outputs ON data to cause the LD **12** to emit light, irrespective of a receiver non-inverting output signal **36** and a receiver inverting output signal **37** output from the LVDS **35**, to thereby perform, using a signal corresponding to a difference between the PD voltage signal **24** and the light amount-determining signal **26**, control for adjusting the amount of light emitted from the LD **12** to a predetermined light amount as follows:

In the case of PD voltage signal **24**>light amount-determining signal **26**: It is determined that the light emission amount of the LD **12** is larger than the predetermined light amount, and the hold capacitor **51** is discharged. As a consequence, the voltage value **28** dependent on the PD current **22** output from the PD **13** is lowered to reduce the laser drive current **32**, whereby the light emission amount of the LD **12** is reduced.

In the case of PD voltage signal **24**<light amount-determining signal **26**: It is determined that the light emission amount of the LD **12** is smaller than the predetermined light amount, and the hold capacitor **51** is charged. As a consequence, the voltage value **28** dependent on the PD current **22** output from the PD **13** is raised to increase the laser drive current **32**, whereby the light emission amount of the LD **12** is increased.

In the case of PD voltage signal **24**=light amount-determining signal **26**: It is determined that the light emission amount of the LD **12** is equal to the predetermined light amount, and the hold capacitor **51** is neither charged nor discharged. As a consequence, both the voltage value **28** dependent on the PD current **22** output from the PD **13** and the laser drive current **32** are neither increased nor reduced.

(2) When the laser diode driving device **11** is in a laser control mode in which the laser driving circuit **21** is set to forcibly turn off the laser (OFF), and the sample/hold circuit **27** is in a holding state, the voltage value **28** set by the sample/hold circuit **27** depending on the PD current **22** output from the PD **13** is held, and the output selection circuit **38** forcibly outputs OFF data to turn off the LD **12** to stop light emission, irrespective of the receiver non-inverting output signal **36** and the receiver inverting output signal **37**.

(3) When the laser diode driving device **11** is in a laser control mode in which the laser driving circuit **21** is set to output data (DATA OUTPUT), and the sample/hold circuit **27**

is in the holding state, the output selection circuit **38** outputs a signal corresponding to the receiver non-inverting output signal **36** or the receiver inverting output signal **37**, using voltage value **28** set by the sample/hold circuit **27** depending on the PD current **22** output from the PD **13**, whereby an electric current is caused to flow through the LD **12** or the resistor **42**.

(4) When the laser diode driving device **11** is reset, the laser driving circuit **21** is brought into a reset state, and the electric current set in the sample/hold circuit **27** is initialized, and at the same time, the output selection circuit **38** forcibly outputs OFF data to turn off the LD **12**.

FIG. **4** is a flowchart of a bias current-determining process executed by the laser diode driving device in FIG. **1** so as to determine a bias current to be applied to the LD.

First, a description will be given of steps S**101** to S**105**.

I. The above-mentioned automatic light amount control is executed so as to adjust the light emission amount of the LD **12** to a light amount P_{aPc} for data light emission.

First in the step S**101**, n is set to 1, and then in a step S**102**, APC light emission is executed with the light amount P_{aPc}. Voltage having a value corresponding to the value of electric current applied to the LD **12** in this state is output between the resistor **54** and ground GND. At this time, the light amount-determining signal **26** is set to $V_{ref\text{-}aPc}$. When the resistance value of the resistor **54** is represented by R_{54}, and an electric current flowing through the LD **12** by I_{aPc}, a voltage V_{54aPc} generated between the resistor **54** and the GND can be calculated by the following equation:

$$V_{54aPc}=I_{aPc}\times R_{54}/40 \qquad \text{A}$$

The voltage value of V_{54aPc} is output to the laser controller **20** via the operational amplifier **55**. In the step S**105**, the electric current I_{aPc} is calculated from the equation A, and the calculated current value is stored in a memory of the laser controller **20**. In this connection, the current value is calculated by the following equation:

$$I_{aPc}=40\times V_{54aPc}/R_{54}$$

II. APC is executed with a light amount $P_{aPc}/2$ which is half the light amount set in the stage I.

When the light amount-determining signal **26** is set to $V_{ref\text{-}aPc}/2$ in the step S**103** so as to cause the LD **12** to emit light in the light amount $P_{aPc}/2$ which is half the light amount set in the stage I, the PD voltage signal **24** becomes higher than the light amount-determining signal **26**, whereby the electric current flowing to the LD **12** is reduced as described in the case (1). A voltage V541/2aPc generated between the resistor **54** and the GND at this time can be calculated by the following equation:

$$V_{541/2aPc}=I_{1/2aPc}\times R_{54}/40 \qquad \text{B}$$

The voltage value of $V_{541/2aPc}$ is output to the laser controller **20** via the operational amplifier **55**. In the step S**105**, the electric current $I_{1/2aPc}$ is calculated from the equation B, and the calculated current value is stored in the memory of the laser controller **20**. Incidentally, the current value is calculated as follows:

$$I_{1/2aPc}=40\times V_{541/2aPc}/R_{54}$$

III. APC is executed with a light amount $P_{aPc}/3$ which is one third of the light amount set in the stage I.

When the light amount-determining signal **26** is set to $V_{ref\text{-}aPc}/3$ in the step S**104** so as to cause the LD **12** to emit light in the light amount $P_{aPc}/3$ which is one third of the light amount set in the case I, the PD voltage signal **24** becomes higher than the light amount-determining signal **26**, whereby the electric current flowing to the LD **12** is reduced as described in the case (1). A voltage V541/3aPc generated between the resistor **54** and the ground GND in association with current flowing through the LD **12** at the time can be calculated by the following equation:

$$V_{541/3aPc}=I_{1/3aPc}\times R_{54}/40 \qquad \text{C}$$

The voltage value of the voltage $V_{541/3aPc}$ is output to the laser controller **20** via the operational amplifier **55**. In the step S**105**, the electric current $I_{1/3aPc}$ is calculated from the equation C, and the calculated current value is stored in the memory of the laser controller **20**. In this connection, the current value is calculated by the following equation:

$$I_{1/3aPc}=40\times V_{541/3aPc}/R_{54}$$

Next, a description will be given of a step S**106** for calculating the laser threshold current value Ith from the light amounts and the current values.

IV. The laser threshold current value Ith is calculated from the relationship between the light amounts P and the electric currents I associated with the LD **12**, which are calculated in the stages I, II, and III.

A laser threshold current value Ith (A) is tentatively calculated from the relationship between the light amounts P_{aPc}, $P_{aPc}/2$, and $P_{aPc}/3$ and the electric currents I_{aPc}, $I_{1/2aPc}$, and $I_{1/3aPc}$ corresponding to the respective light amounts. Since the light amount P and the electric current I are calculated as P_{aPc} and I_{aPc} in the stage I and as $P_{aPc}/2$, and $I_{1/2aPc}$ in the stage II, the laser threshold current value Ith (A) can be calculated by the following equation:

$$Ith(A)=I_{aPc}-P_{aPc}\times(I_{aPc}-I_{1/2aPc})/(P_{aPc}-P_{aPc}/2) \qquad \text{D}$$

Then, a laser threshold current value Ith (B) is tentatively calculated from the relationship between the light amounts P and the electric currents I in the stages II and III. Since the light amount P and the electric current I are calculated as $P_{aPc}/2$ and $I_{1/2aPc}$ in the stage II, and as $P_{aPc}/3$ and $I_{1/3aPc}$ in the stage III, the laser threshold current value Ith (B) can be calculated by the following equation:

$$Ith(B)=I_{1/2aPc}-P_{aPc}/2\times(I_{1/2aPc}-I_{1/3aPc})/(P_{aPc}/2-P_{aPc}/3) \qquad \text{E}$$

Finally, a description will be given of steps S**107** to S**109**.

V. The two laser threshold current values calculated in the stage IV are compared with each other to thereby determine a bias current to be applied to the LD **12**.

If it is determined in the step S**107**, based on the result of comparison between the laser threshold current values Ith (A) and Ith (B), that an error of Ith (A) with respect to Ith (B) is e.g. within 5%, it is judged that the relationship between the light amount and the electric current corresponds to that between linear expressions denoted by E**1** and D**1** in FIG. **5** (which means that the relationship between the light amount of which values are P_{aPc}, $P_{aPc}/2$, and $P_{aPc}/3$ and the current of which respective associated values are I_{aPc}, $I_{1/2aPc}$, and $I_{1/3aPc}$ can be expressed by a single linear expression). In this case, it can be said that the calculated laser threshold current value Ith and the actual laser threshold current value Ith of the LD **12** are approximately identical in characteristic, and therefore in the step S**108**, the bias current value is determined using the laser threshold current value Ith (A).

Now, the reason for determining the bias current value using the laser threshold current value Ith (A) will be explained. The voltage V_{54} generated between the resistor **54** and the GND is used as a value for use in calculating the laser threshold current value Ith, but when the light amount of the

LD **12** is small, due to a low value of the voltage V_{54}, an error increases in the calculating the laser threshold current value Ith with high accuracy.

Another reason is that when the LD **12** is a VCSEL, the rated amount per se of light that can be emitted is small, and hence not only further reduction of the value of the voltage V_{54}, but also reduction of the output of the PD **13** occur, which causes an increase in error in the APC.

The bias current Ib is calculated in the step S**108**, provided that the bias current value is set to 90% of the laser threshold current value Ith (A), by the following equation:

$$Ib=0.9\times Ith(A)$$

On the other hand, if it is determined in the step S**107**, based on the result of comparison between the laser threshold current values Ith (A) and Ith (B), that the error of Ith (A) with respect to Ith (B) is more than 5%, it is judged that the relationship between the light amount and the electric current corresponds to that between linear expressions denoted by E**2** and D**2** in FIG. **6** ((which means that the relationship between the light amount of which values are P_{aPc}, $P_{aPc}/2$, and $P_{aPc}/3$ and the current of which respective associated values are I_{aPc}, $I_{1/2aPc}$, and $I_{1/3aPc}$ cannot be expressed by a single linear expression). In this case, it can be said that the calculated laser threshold current value Ith and the actual laser threshold current value Ith of the LD **12** are largely different in characteristic.

Therefore, in the step S**109**, n is incremented by 1 so as to reduce the light amount to a lower level than the light amount $P_{aPc}/3$ in which light was emitted in the step S**104**, and then in the step S**104**, APC is executed with a light amount $P_{aPc}/4$ which is one forth of the light amount P_{aPc}. Then, in the step S**106**, a laser threshold current value Ith (C) is calculated from the light amounts $P_{aPc}/3$ and $P_{aPc}/4$ and the currents $I_{1/3aPc}$ and I1/4aPc corresponding to the respective light amounts. Further, in the step S**107**, the laser threshold current values Ith (B) and Ith (C) are compared in the same manner as described above, to thereby determine whether or not the error between the two values falls within 5%.

This step is repeatedly carried out until the error between the two values falls within 5%. By doing this, it is possible to set the bias current accurately even when the laser diode has a non-linear characteristic having a maximum output light amount on its non-linear portion as shown in FIG. **6**.

It should be noted that APC is always executed with the light amount P_{aPc} during a time period over which the LD **12** performs data output, e.g. in sampling timing in FIG. **2** by way of example. Further, the steps S**103** et seq. for determining the bias current value Ib may be carried out during a time period over which data output is not performed as in FIG. **2**. In such a case, when n is set to 1 and it is determined in the step S**107** that the error is more than 5%, and when the sequence for determining the bias current value Ib is to be operated again, the operation may be started by setting n to 2. Although in the present embodiment, control is performed for a single laser diode, it is possible to control a plurality of laser diodes.

As described heretofore, by calculating a bias current value from electric current values corresponding, respectively, to three or more kinds of light amounts of a laser diode, it is possible to set the bias current value Ib close to the threshold current value Ith of the laser diode even when the light amount-electric current characteristic is like the one shown in FIG. **6**.

Therefore, trouble in data transfer in an optical communication apparatus or degradation of image quality in an image forming apparatus can be suppressed. Further, since the bias current value can be set close to the threshold current value Ith even when the light amount-electric current characteristic has no linear region, it is possible to perform precise light amount control e.g. even for a VCSEL (semiconductor vertical-cavity surface-emitting laser) having one or more light emitting points.

While the present invention has been described with reference to an exemplary embodiment, it is to be understood that the invention is not limited to the disclosed exemplary embodiment. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all modifications, equivalent structures and functions

This application claims priority from Japanese Patent Application No. 2007-179915 filed Jul. 9, 2007, which is hereby incorporated by reference herein in its entirety.

What is claimed is:

1. A laser diode driving device comprising:

a light amount-detecting unit adapted to detect an amount of light emitted from a laser diode;

a light amount-determining unit adapted to determine an amount of light to be emitted from the laser diode;

a light amount control unit adapted to control the laser diode to emit light in the light amount determined by said light amount-determining unit; and

a bias current value-determining unit adapted to determine a bias current value based on results of light emission performed by the laser diode in three or more light amounts determined by said light amount-determining unit,

wherein said bias current value-determining unit determines the bias current value through comparison between (a) a first bias current value obtained from a first line calculated through two points corresponding to electric current values associated with two of the three or more light amounts, and (b) a second bias current value obtained from a second line calculated through two points corresponding to electric current values associated with two of the three or more light amounts, and

wherein a point of the two points associated with the first line is different than a point of the two points associated with the second line.

2. A laser diode driving device as claimed in claim **1**, wherein said bias current value-determining unit determines the bias current value based on electric current values of respective electric currents applied to the laser diode when the laser diode is caused to emit light in two different light amounts.

3. A laser diode driving device as claimed in claim **1**, wherein said bias current value-determining unit determines the bias current value based on electric current values of respective electric currents applied to the laser diode when the laser diode is caused to emit light in two light amounts except a maximum light amount which are selected from a three or more light amounts.

4. A laser diode driving device as claimed in claim **1**, wherein the laser diode is a semiconductor vertical-cavity surface-emitting laser.

5. A laser diode driving device as claimed in claim **1**, wherein the laser diode is a semiconductor vertical-cavity surface-emitting laser having one or more light emitting points.

6. An optical scanning device comprising:

a light amount-detecting unit adapted to detect an amount of light emitted from a laser diode;

a light amount-determining unit adapted to determine an amount of light to be emitted from the laser diode;

a light amount control unit adapted to control the laser diode to emit light in the light amount determined by said light amount-determining unit; and

a bias current value-determining unit adapted to determine a bias current value based on results of light emission performed by the laser diode in three or more light amounts determined by said light amount-determining unit,

wherein said bias current value-determining unit determines the bias current value through comparison between (a) a first bias current value obtained from a first line calculated through two points corresponding to electric current values associated with two of the three or more light amounts, and (b) a second bias current value obtained from a second line calculated through two points corresponding to electric current values associated with two of the three or more light amounts, and

wherein a point of the two points associated with the first line is different than a point of the two points associated with the second line.

7. An optical scanning device as claimed in claim **6**, wherein said bias current value-determining unit determines the bias current value based on electric current values of respective electric currents applied to the laser diode when the laser diode is caused to emit light in two different light amounts.

8. An optical scanning device as claimed in claim **6**, wherein said bias current value-determining unit determines the bias current value based on electric current values of respective electric currents applied to the laser diode when the laser diode is caused to emit light in two light amounts except a maximum light amount which are selected from a three or more light amounts.

9. An optical scanning device as claimed in claim **6**, wherein the laser diode is a semiconductor vertical-cavity surface-emitting laser.

10. An optical scanning device as claimed in claim **6**, wherein the laser diode is a semiconductor vertical-cavity surface-emitting laser having one or more light emitting points.

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